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LONGITUDINAL STABILITY AND AERODYNAMIC CHARACTERISTICS OF A REENTRY VEHICLE CONFIGURATION HAVING AN EXTENDABLE LEADING EDGE AT A MACH NUMBER OF 10.03 AND ANGLES OF ATTACK FROM 50° TO 90°

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Langley Station, Hampton, Va.

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LONGITUDINAL STABILITY AND AERODYNAMIC CHARACTERISTICS OF A REENTRY VEHICLE CONFIGURATION HAVING AN EXTENDABLE LEADING EDGE AT A MACH NUMBER OF 10.03 AND ANGLES OF ATTACK FROM 50° TO 90°*

By Charles F. Whitcomb and Odell A. Morris

SUMMARY

An investigation of the longitudinal aerodynamic and stability characteristics of a simplified version of a proposed reentry vehicle having an extendable leading edge has been conducted at a Mach number of 10.03 for angles of attack from 50° to 90° in the Langley 15-inch hypersonic flow apparatus. The leading edge is extended forward to provide trim at high angles of attack for reentry and is retracted to provide trim at the lower angles of attack for maneuvering and landing.

The model is stable through the angle-of-attack range for all leading-edge extensions and an increase in the leading-edge extension resulted in a corresponding shift in center-of-pressure location.

INTRODUCTION

The National Aeronautics and Space Administration is conducting investigations of a wide variety of configurations designed for controlled reentry into the earth's atmosphere. (See, for example, refs. 1 to 4.) One vehicle concept which has been proposed and forms the basis of the study herein has a variable leading-edge extension of the heat shield to provide trim at high angles of attack for reentry and trim at lower moderate-lift angles of attack for maneuvering and landing. The heat shield would be extended forward at high angles of attack and retracted at the lower angles of attack as necessary to obtain the desired center-of-pressure locations. The low subsonic static and oscillatory stability characteristics of a model of such a vehicle are presented in reference 5.

The purpose of the present tests was to investigate the static stability characteristics of a model of the proposed reentry configuration in the Langley

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*Title, Unclassified.

15-inch hypersonic flow apparatus at a Mach number of 10.03 for angles of attack from 50° to 90°. The data are presented here for a test Reynolds number of 0.33×10^6 based on the maximum chord length of the basic or zero-extension configuration.

SYMBOLS

All data presented herein are referred to the stability system of axes. Pitching moments were taken about a reference point located at 25 percent of the maximum chord of the basic or zero-extension model. All coefficients are based on the planform area and maximum chord of the zero-extension model.

c	maximum chord of zero-extension model, in.
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_m	pitching-moment coefficient about 25 percent c, $\frac{\text{Pitching moment}}{qSc}$
C_p	local pressure coefficient
$C_{p,max}$	stagnation pressure coefficient behind a normal shock
D	diameter
L/D	lift-drag ratio
M	Mach number
q	dynamic pressure, lb/sq in.
R	radius
S	projected planform area of zero-extension model, sq in.
α	angle of attack, deg
δ	angle between body surface and velocity vector, deg

MODEL

A sketch of the proposed reentry vehicle is presented in figure 1. When the heat shield is fully retracted, the vehicle has a nearly elliptic longitudinal cross section with a blunt leading edge and a raised canopy. The planform has

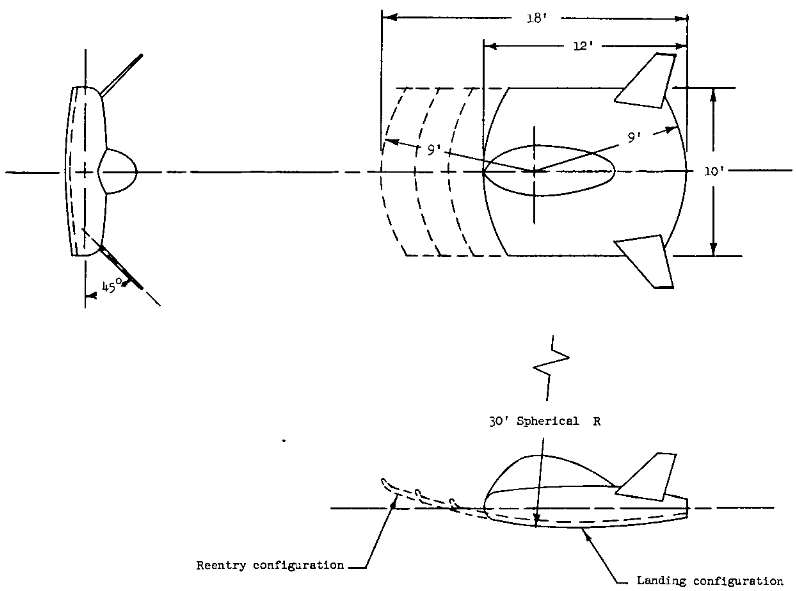


Figure 1.- Three-view sketch of the proposed reentry vehicle with extendable leading edge.

straight sides with circular-arc leading and trailing edges. The top and bottom surfaces are segments of a relatively large radius sphere. The top-mounted twin tail surfaces are all-movable controls which are retracted for reentry and canted outward 45° for low-speed flight. The extendable heat shield is moved forward 50 percent of the basic vehicle maximum chord for reentry and fully rearward for landing.

Details of the model used in the present investigation are shown in figure 2. Four models were used, each representing a different position of the heat shield. The heat shield was extended forward 0, 16.8, 33.4, and 50 percent of the basic-model maximum chord and the respective model thickness dimensions were 16.5, 12.2, 14.2, and 16.9 percent of the individual model chords. The top-mounted twin tail surfaces were not used. The model was constructed of stainless steel to withstand the high stagnation temperature used in the hypersonic test facility.

APPARATUS AND TESTS

The investigation was conducted in the Langley 15-inch hypersonic flow apparatus at a Mach number of 10.03, a stagnation pressure of about 785 pounds per square inch absolute, and a stagnation temperature of about 1,450° F. Some of

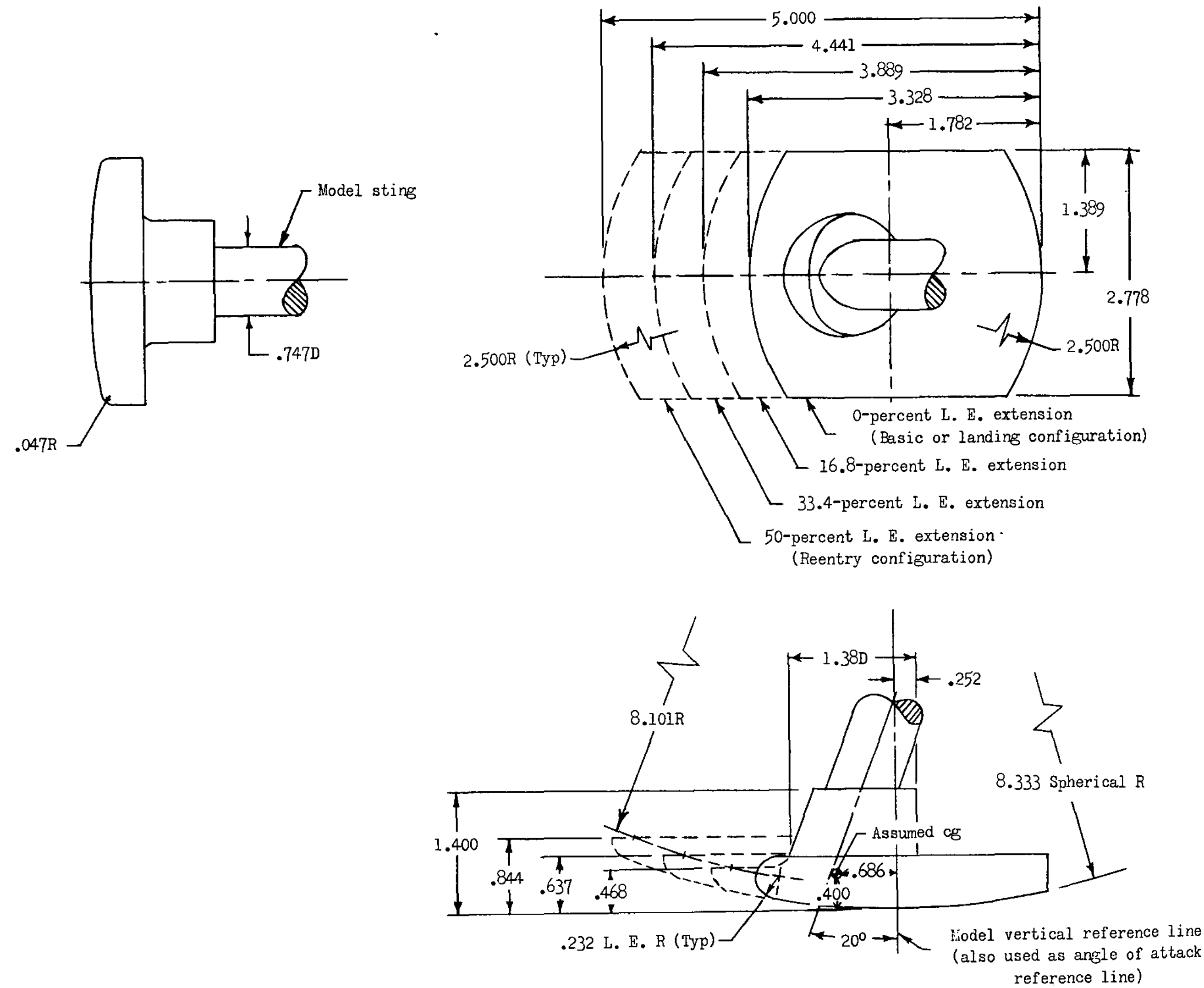


Figure 2.- Details of the model configurations used in the present investigation. All dimensions are in inches.

the airflow characteristics of the facility are presented in reference 6. The test Reynolds number, based on the maximum chord length of the basic or fully retracted configuration, was 0.33×10^6. The model was mounted on a water-cooled, six-component, strain-gage balance which in turn was sting mounted to the tunnel support system. The model was tested at angles of attack from 50° to 90°. Since the balance cavity base pressure is assumed to be equal to the static pressure on the downstream side of the model, no adjustments have been made to the measured normal or axial forces of the model. The estimated maximum errors of the measured quantities in this investigation are as follows:

C_L . . . . ±0.040
C_D . . . . ±0.015
C_m . . . . ±0.007

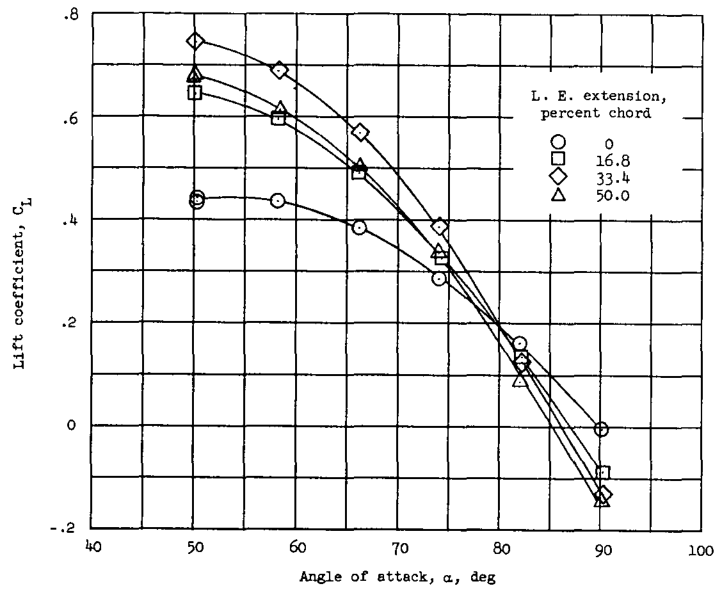
The estimated maximum error in α was $\pm 0.1^\circ$ and in M was ±0.15.

RESULTS AND DISCUSSION

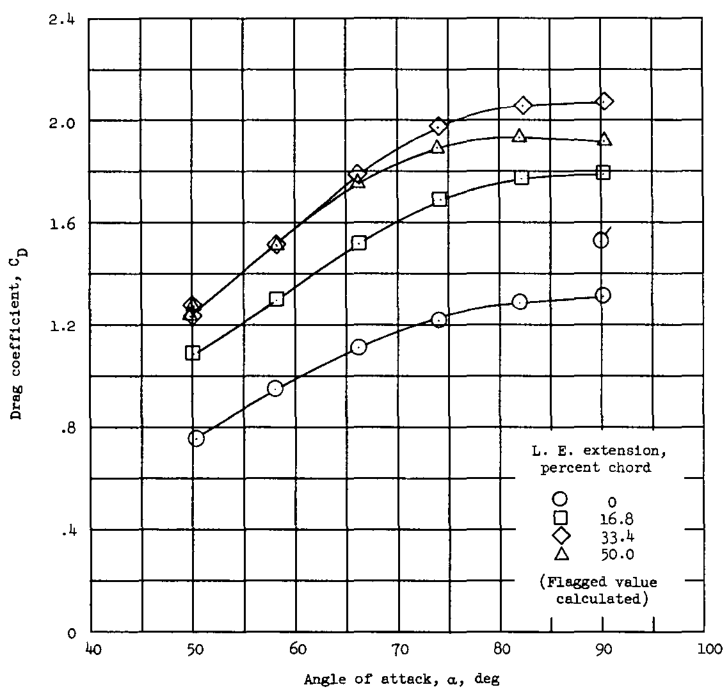
The longitudinal stability and aerodynamic characteristics of the four leading-edge-extension configurations of the model for a Mach number of 10.03 and an angle-of-attack range from 50° to 90° are presented in figure 3. The leading-edge extension of the heat shield was extended forward 0, 16.8, 33.4, and 50 percent of the basic-model maximum chord. The lift characteristics of the 0-percent-extension or basic configuration, presented in figure 3(a), show a maximum lift coefficient of 0.445 at $\alpha = 53^\circ$ and a lift coefficient of zero at $\alpha = 90^\circ$. The lift coefficients of the configurations with leading edges extended are greater at the lower test angles of attack than the maximum lift coefficient of the basic configuration. This is primarily due to the fact that all the coefficients are based on the projected planform area of the basic model. However, the lift coefficients for the 50-percent-extended configuration are less than those for the 33.4-percent-extended configuration. This trend was predicted by modified Newtonian theory and results from a decrease in the total lift force on the largest model. This force decrease is associated with the decreased aspect ratio and increased thickness ratio of this model, as compared with those of the 33.4-percent-extended model.

The drag characteristics of the four configurations are presented in figure 3(b). The measured drag coefficient of the basic configuration at $\alpha = 90^\circ$ is 1.31. The estimated value for this configuration from modified Newtonian theory $\left(C_p = C_{p,max} \sin^2\delta\right)$ by using reference 7 is 1.52. In making the theoretical estimate, the rounded leading edge of the model was not considered and this could result in the estimated value being somewhat higher than the measured value. For the leading-edge-extended configurations, the measured values of drag coefficient are larger than those for the basic configuration over the test angle-of-attack range. The primary reason for this result is that all the coefficients are based on the basic model projected planform area. It should be noted, however, that the 50-percent-extension values are less than the 33.4-percent-extension values over the higher test angle-of-attack range. This trend was not predicted by modified Newtonian theory and indicates that the variations in the model thickness ratio and aspect ratio create a three-dimensional pressure-relieving effect which becomes more significant as the leading-edge area is increased.

The variation of the untrimmed lift-drag ratio with angle of attack for the four model configurations is presented in figure 3(c). The variation is nearly linear for all configurations. The maximum lift-drag ratio does not fall within the test angle-of-attack range for any of the configurations. For these tests the maximum value is approximately 0.6 and occurs at $\alpha = 50^\circ$.

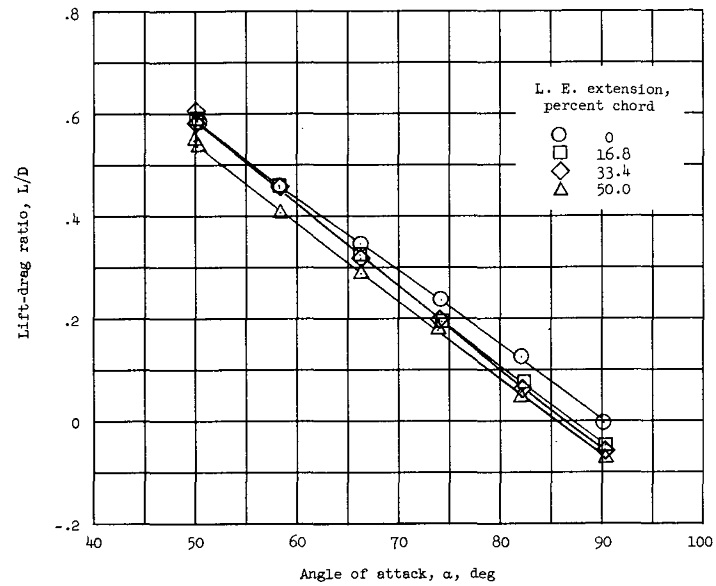


(a) Lift coefficient.

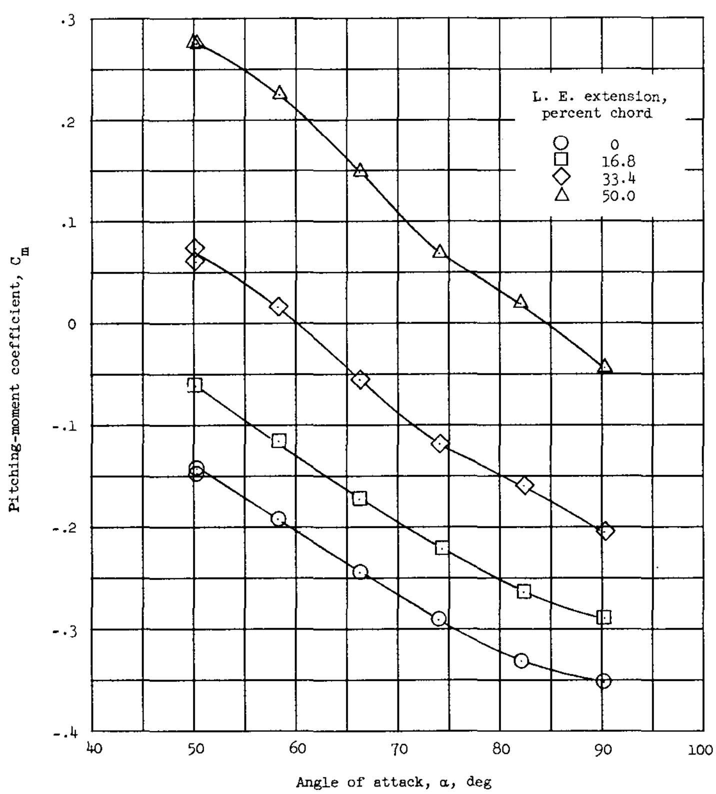


(b) Drag coefficient.

Figure 3.- Longitudinal aerodynamic and stability characteristics of the model with four leading-edge-extension configurations.

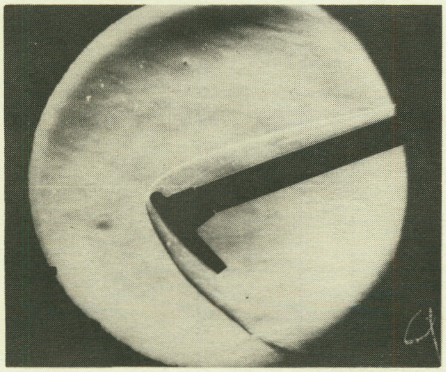


(c) Lift-drag ratio.

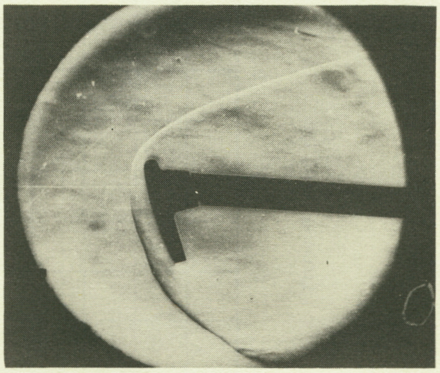


(d) Pitching-moment coefficient.

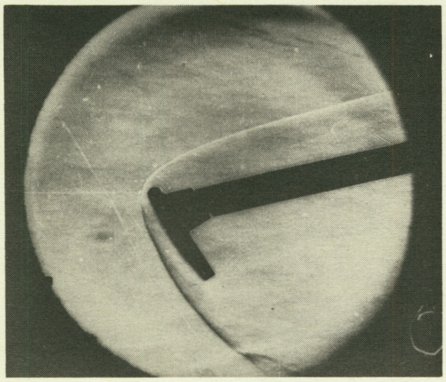
Figure 3.- Concluded.



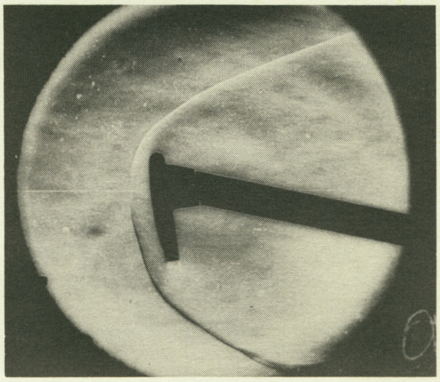
$\alpha = 50.3^{\circ}$



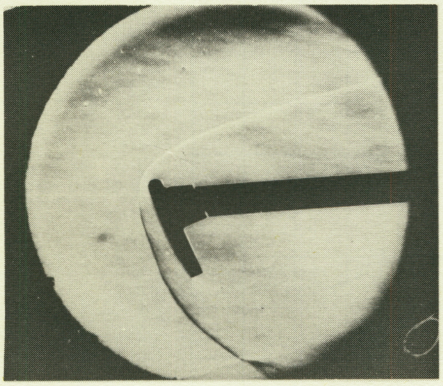
$\alpha = 74.0^{\circ}$



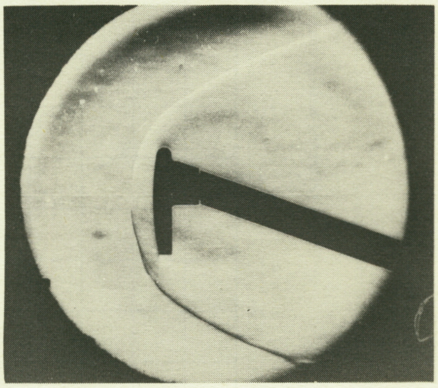
$\alpha = 58.1^{\circ}$



$\alpha = 82.0^{\circ}$



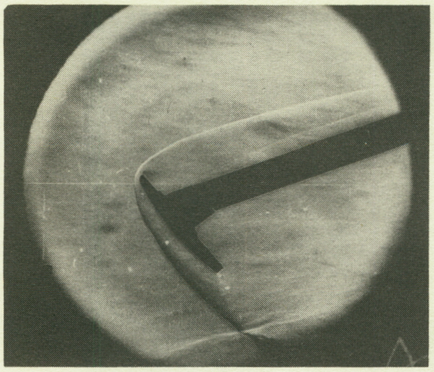
$\alpha = 66.2^{\circ}$



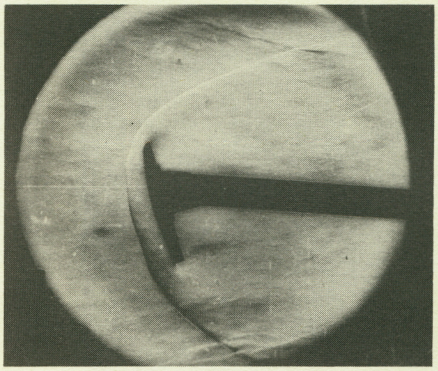
$\alpha = 90.1^{\circ}$

(a) 0-percent-chord leading-edge extension. L-63-4702

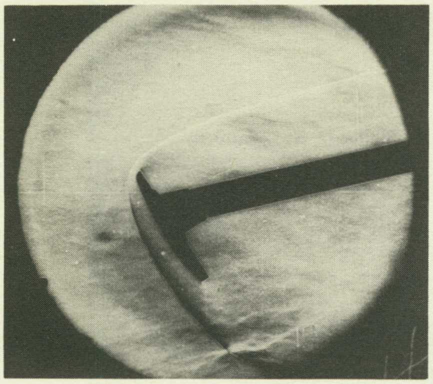
Figure 4.- Schlieren photographs of model with various amounts of leading-edge extension.



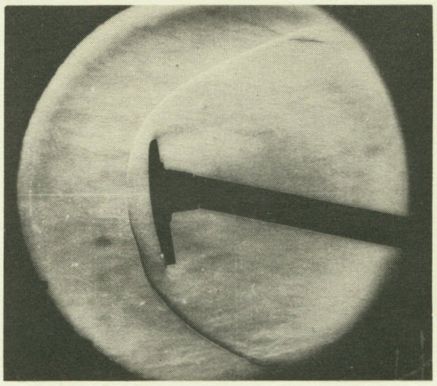
$\alpha = 50.1^{\circ}$



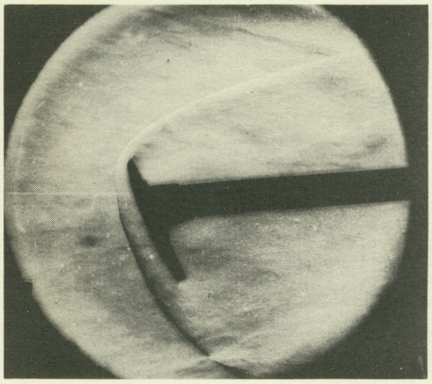
$\alpha = 74.2^{\circ}$



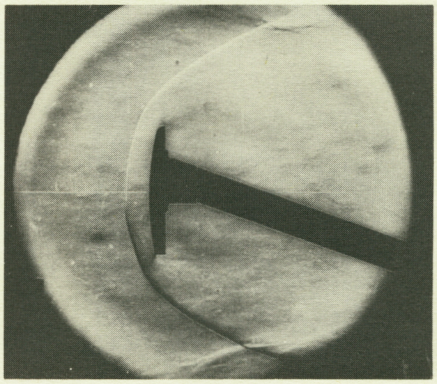
$\alpha = 58.2^{\circ}$



$\alpha = 82.2^{\circ}$



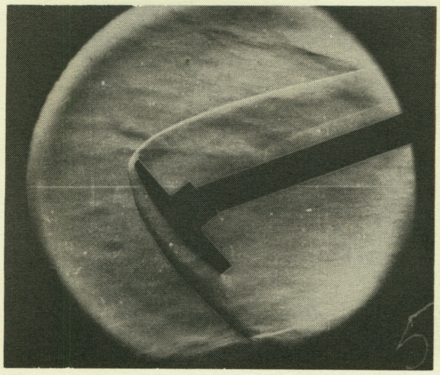
$\alpha = 66.1^{\circ}$



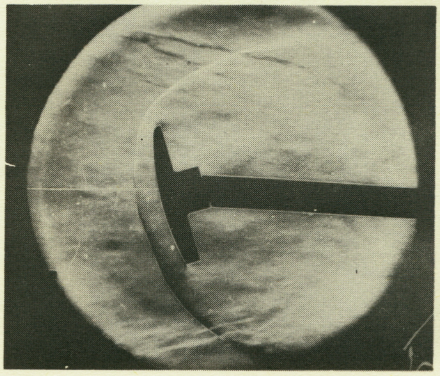
$\alpha = 90.2^{\circ}$

(b) 16.8-percent-chord leading-edge extension. L-63-4703

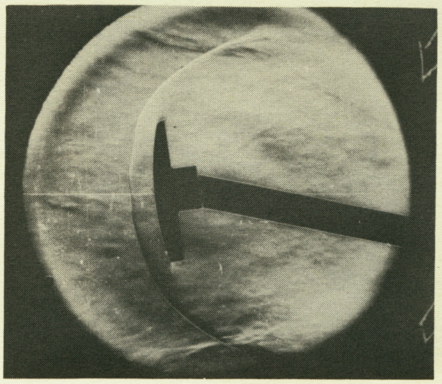
Figure 4.- Continued.



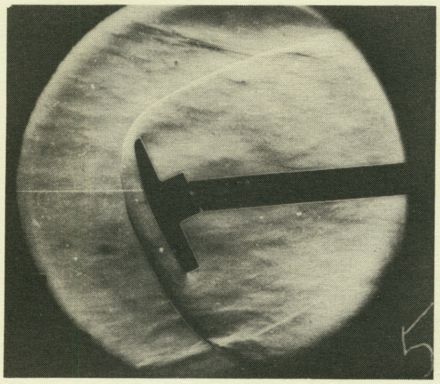
$\alpha = 50.1^\circ$



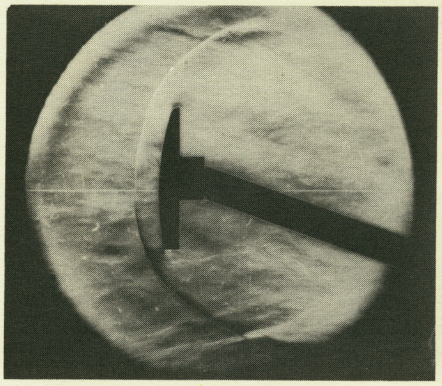
$\alpha = 74.0^\circ$



$\alpha = 82.3^\circ$



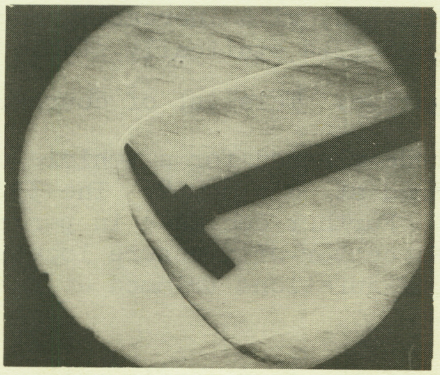
$\alpha = 66.2^\circ$



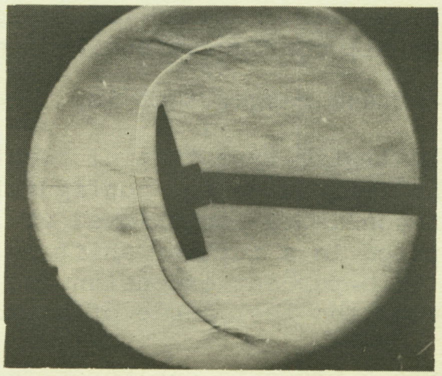
$\alpha = 90.2^\circ$

(c) 33.4-percent-chord leading-edge extension. L-63-4704

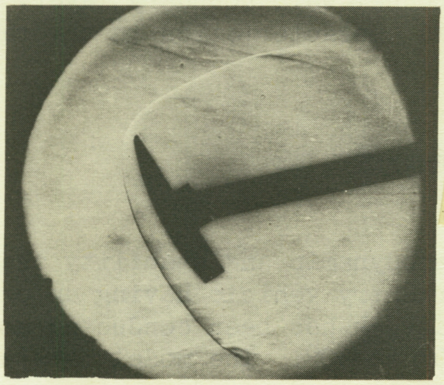
Figure 4.- Continued.



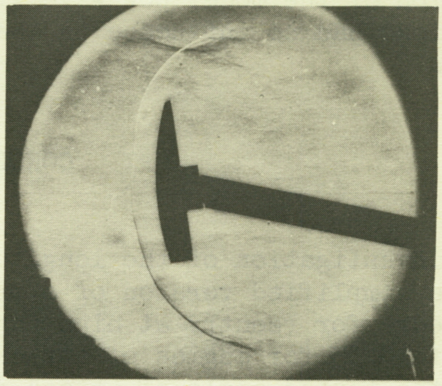
$\alpha = 49.9^{\circ}$



$\alpha = 73.9^{\circ}$



$\alpha = 58.3^{\circ}$



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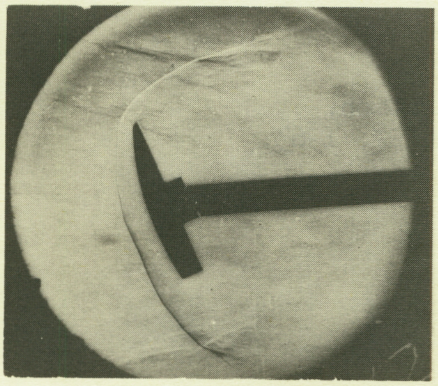
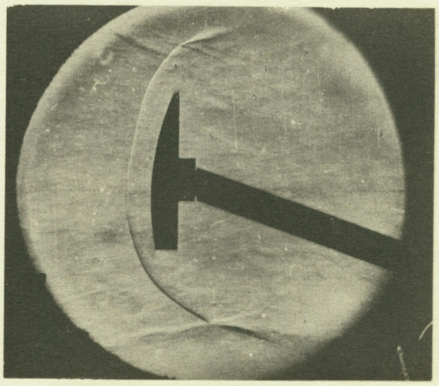


$\alpha = 66.2^{\circ}$



$\alpha = 90.2^{\circ}$

(d) 50.0-percent-chord leading-edge extension. L-63-4705

Figure 4.- Concluded.

The pitching-moment characteristics of the four configurations are presented in figure 3(d). The negative slope of the pitching-moment coefficients (measured about the quarter chord of the basic configuration) with increasing angle of attack for all configurations indicates the model is statically stable for this angle-of-attack range, that is, $\frac{\partial C_m}{\partial \alpha}$ is negative. This is, of course, desirable for the ballistic-type initial reentry attitude planned for a vehicle of this type. The full-extension configuration trimmed at $\alpha = 84.5^{\circ}$. The 33.4-percent-extension configuration trimmed at $\alpha = 60^{\circ}$. Further decrease in percent extension resulted in a further shift in the model center-of-pressure location such that the 16.8-percent extension and basic configurations trimmed at angles of attack below the test angle-of-attack range.

Figure 4 presents schlieren photographs of the four configurations taken during the investigation. The disturbances appearing in some of the photographs in the upper and lower portions of the schlieren field of view are due to the interaction of the model bow wave with the tunnel-wall boundary layer. These interactions had no influence on the measured characteristics in the range of the tests.

CONCLUDING REMARKS

An investigation of the longitudinal aerodynamic and stability characteristics of a simplified version of a proposed reentry vehicle having an extendable leading edge for reentry at high angles of attack has been conducted at a Mach number of 10.03 for angles of attack from 50° to 90°. The model is stable through the tested angle-of-attack range for all leading-edge extensions and an increase in the leading-edge extension resulted in a corresponding shift in center-of-pressure location.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., June 27, 1963.

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